A

DESCRIPTION

OF

ABBOTT'S HOROMETER,

AND

ABBOTT'S GEODETIC CHART,

WITH

DIRECTIONS FOR THEIR USES

IN

PRACTICAL NAVIGATION.

1033.3
A131

S. RUDDOCK, PRINTER, NEW LONDON, CONN.
1852.

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ENTERED, according to the Act of Congress, in the year 1852, by
AMOS ABBOTT,
in the Clerk's Office, of the District Court, for the Southern District
of New York.

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RECOMMENDATIONS.

Cambridge, 8th July, 1852.

Amos Abbott has exhibited to us an instrument, which he calls a "Horometer," designed to determine by a mechanical process, the hour and minute of the day from given observations of the sun's altitude, with sufficient accuracy for the ordinary purposes of navigation.

We certify that the scientific principles on which this instrument is constructed, are correct, and it appears to have fully accomplished the object for which it was designed. We believe that navigators who will undertake to use the Horometer, will become attached to it as an useful and ready test of their numerical computations. It may even be recommended as a safe substitute for the formulae, and especially because it does not appear to be liable to those species of error which computors are prone to commit in rapid and hasty calculations.

We also recommend Mr. Abbott's Geodetic Chart, on account of its simplicity and its facility in aiding the navigator in determining his position and path upon the ocean.

CHARLES HENRY DAVIS,
Lieut. Supt. Naut. Alm'c.
BENJAMIN PIERCE,
Perkins Professor of Astronomy and Mathematics in
Harvard College, and consulting Astronomer
of the Nautical Almanac.

Cambridge, July 10, 1852.

I have examined Mr. Abbott's Horometer, and am satisfied that it is constructed on correct principles.

It appears to be well designed for giving the time at sea from altitudes of the sun, with an accuracy sufficient for all ordinary purposes, by a very simple and readily applied mechanical process, affording a valuable and easy check on the calculations of the navigator.

G. P. BOND,
Astronomical Assistant at the
Observatory of Harvard College.

Boston, Oct. 15th. 1852.

Amos Abbott, Esq., Dear Sir—I have read your pamphlet describing the "Horometer," and "Geodetic Chart," and have also examined your nicely graduated instrument. I have to say that I think both will much facilitate the calculations of seamen, and conduce to the safety of navigation.

I am very truly, your servant.

R. B. FORBES.

To Amos Abbott, Esq., Portsmouth, N. H.

ERRATA.

On page 8, line 18, for "VI" read IV.
On page 8, last line, for "altitude" read latitude.
On page 16, line 19, for "The latitude" read In latitude.
On pages 17 and 22, for "substract" read subtract.

TO THE READER.

The following pages are put forth for the purpose of introducing to public attention "ABBOTT'S HOROMETER" and "ABBOTT'S GEODETIC CHART."

The Horometer is an instrument for solving various problems in navigation, without the logarithmic process. The Chart, is designed to be used in connection with the Horometer, by the aid of which, the workings of problems are greatly shortened; yet it is entirely independent in its capabilities, and its use even without that instrument, will be found to be highly advantageous.

By those who are familiar with Capt. Sumner's "New Method of Finding a Ship's Position at Sea," the Chart will be readily understood. It is designed to facilitate and simplify the practice of this "new method," so fully and clearly explained in the valuable book bearing the above title.

The Horometer is not intended to supersede any other instrument, but only to supply a deficiency in the means of readily securing accurate navigation.

Should the necessity of such an instrument be questioned, the careful attention of the reader is invited to the following considerations.

First—*Security against errors of calculation.*

By using the Horometer, mistakes in calculation for semi-diameter, dip, refraction and parallax, are entirely avoided, as well as those which occur from unskillful or hasty computations. An error can scarcely happen in the use of the Horometer, otherwise than in reading; and if the instrument is employed in connection with the usual method by figures, a mistake of any consequence, is sure to be detected. Nothing is more easy than to make mistakes in calculation, but it is often quite difficult to detect them. It is common experience, that the same mistake is liable to be repeated over and over.

One instance of the many that have actually occurred, is here given for illustration.

A gentleman familiar with working time, wishing to test the accuracy of the Horometer—in which he had already acquired great confidence, found his logarithmic result to differ from the reading of the instrument about two minutes of time; he reviewed his work several times very carefully, and pronounced it correct; to be doubly sure, he rubbed all out and commenced anew, but with the same result. A friend who looked over the work, was also sure that all was right. Sentence of condemnation was about to be passed upon the instrument, when the discovery was made, that in correcting the logarithmic cosine for seconds, the correction had been added, instead of subtracted, as should have been done; this mistake was repaired, and the difference was found to be just four seconds of time from the instrument.

The gentleman then remarked, that at sea, without the Horometer, he should have had perfect confidence in his work, yet it might have led him into a fatal error of thirty miles in longitude.

Again, it sometimes happens that the true pos-ition of the ship is so far from where it is supposed to be, that the calculations, though correct, are rejected, when such a test as the Horometer affords, would have given confidence in those calculations.

Second—*Saving of time and labor.*

The advantage of the instrument, as a labor-saving machine, excepting in cases of sickness, where the fatigue of calculation could not be endured, might be thought to be of little consequence; but if facility in obtaining the time will induce navigators to make more frequent observations; then the Horometer is of great importance, because it will furnish means for closer navigation, at less cost of time and labor.

This saving of time, and simplicity in the process of solving the problems, may in some cases be of great value. Let us suppose a case, likely to occur. After a day or two of cloudy weather, it clears up in the P. M., but not affording an opportunity for taking an observation of the sun.

In the course of the star-light evening, land is suddenly discovered or breakers are heard in the distance. Altitudes of two known stars, differing in azimuth, are taken, and the time is read off on several latitudes for each altitude, from which the true time is found, and two lines of position are projected upon the Geodetic Chart; these give at once the latitude and longitude of the ship. Now to perform all this in the usual way, would consume a great deal of time. Two altitudes would have to be corrected for dip and refraction, and time worked four different times; with all the excitement and hurry incident to such an occasion, it would be wonderful if no mistake was made. The Horometer would save the making of between two and three hundred figures, and looking out fourteen different logarithms, to say nothing of the adding, subtracting and dividing. But this is not all. In assuming the two latitudes after a day or two has passed without an observation, it would not be at all improbable that the wrong latitudes should be assumed; in which case half as much more time would be required, which might be saved by the Horometer.

To navigators of whaling ships, the considerations of saving of time, and convenience, are of especial value.

In the midst of "taking oil," the condition of a ship is generally unfavorable to mathematical computations, and observations are in consequence neglected.

In such cases, by the aid of the Horometer, the position of the ship may be determined, at times when the inconvenience of the common method would render an observation impracticable.

Third—*The Horometer shows the effect of any error.*

An error in latitude of one degree will sometimes make a difference of ten minutes of time, and sometimes an error of two degrees of latitude would not make an error of five seconds of time. The Horometer would show at a glance what error in time, an error in latitude, altitude, or polar distance, would produce. It is often not only desirable to know when a star or the sun is due east or west, so as to avoid an error from not having the latitude; but how much before or after that time it will do to depend on one observation to get the longitude. This can be seen in a moment by the instrument, but would be tedious beyond endurance to calculate by logorithms.

Fourth—*This instrument is not a mere calculating machine.*

It suggests many important and practical questions, and furnishes answers to them. It explains itself. It gives a person in a few moments, an intelligent understanding of the general principles of the science.

Said an intelligent young man, "I have Bowditch at my finger's ends, but I never knew the first thing of the whys and the wherefores, and I have learned more of navigation since I have been standing here looking at the Horometer, than I ever knew before."

Fifth—*The opinion of Scientific Men.*

Of some fifteen or twenty scientific gentlemen who have carefully examined the "Horometer," all have without exception, expressed favorable opinions in regard to it. One of our most intelligent and practical navigators, had an opportunity of testing a rough model of the instrument on a short voyage, and he gave it as his opinion that it would give the time more correctly than it was usually found at sea; and that it would be of great practical utility. Testimonials to any extent can be readily obtained, showing that the instrument is worthy of the confidence and patronage of MASTERS OF VESSELS, SHIP OWNERS, and INSURANCE COMPANIES.

INTRODUCTION.

DEFINITION OF TERMS.

The earth may be regarded as a sphere or globe, revolving on its axis from west to east, once in twenty-four hours. The ends of the axis are called "*poles.*"

Lines drawn over the globe from one pole to the other, are called "*lines of longitude*" or "*meridians.*"

At right angles to lines of longitude, and equidistant from the poles, a line drawn around the earth is called the "*Equator,*" and all lines parallel to the equator, are called "*parallels of latitude.*"

Latitude is measured from the equator, on some meridian or line of longitude.

Longitude is measured from some one meridian to another, on some parallel of latitude.

One hundred-and-eighty circles of longitude equi-distant from each other at the equator, and the same number of equi-distant parallels of latitude, would divide the surface of the globe into degrees of latitude, and degrees of longitude.

The heavens or sky, may be regarded as a concave or hollow sphere, studded with fixed stars, and within this sphere, the sun and moon, earth and planets, perform their revolutions.

The earth performs a revolution round the sun once in a year, and we may imagine the path or orbit which it makes in its revolution, to be the circumference of a circle projected upon the sky. This circle is called the "*Ecliptic.*" With the ecliptic drawn upon the sky, we may imagine lines of latitude drawn parallel to it, and lines of longitude perpendicular to it—as was supposed to be done on the earth.

In speaking of latitude and longitude of a heavenly body, reference is made to lines of latitude and longitude of the heavens.

The ecliptic and equator, are not parallel to each other, for the earth in its revolution round the sun, does not move at right angles to its own axis, but at an inclination from a right angle, of 23° 28′; there is therefore, the same inclination between the equator and the ecliptic.

We may now suppose these terrestrial latitudes and longitudes, to be circles, the circumference of which we may imagine to be enlarged, till they are projected upon the sky.

Terrestrial latitude projected upon the sky, is called "*Circles of Declination.*" Terrestrial longitude projected upon the sky, receives the name of "*Right Ascension.*"

The equator thus transferred, is called the "*Equinoctial.*" It crosses the ecliptic at two points. The circle of right ascension, which passes through these two points is called the "*Equinoctial Colure.*"

The earth in its revolution round the sun, passes the equinoctial colure about the 20th of March, and the 20th of September.

Right ascension is reckoned eastward, commencing from the equinoctial colure, which the sun crosses in March.

There are two ways of defining the position of a heavenly body. First by its latitude and longitude, secondly, by its declination and right ascension.

The earth in its progress round the sun from west to east, refers the sun to different longitudes, so that the sun appears to move toward the east, making one revolution a year. The sun therefore, unlike the fixed stars, is constantly changing in longitude, right ascension, and declination, but not in latitude.

The point over head to a person on any part of the earth is called the "*Zenith,*" and a circle ninety degrees from this point, is called the "*apparent horizon.*" A circle parallel to the apparent horizon, which would cut the centre of the earth, is called the "*true horizon.*" The difference between the apparent and true horizon, is called the "*horizontal parallax.*"

The circle which terminates the view upon a water level, may be called the "*sensible horizon.*" The difference between the apparent and sensible horizon, is called the "*Dip.*" The dip therefore depends upon the height of the observer above the surface. The square root of the height in feet above the surface, gives the dip, in minutes of a degree, nearly.

Lines drawn from the zenith to the horizon, cut the horizon at right angles, and are called "*Verticals.*"

The angular height of a body, measured from the horizon on a vertical, is called "*Altitude.*"

The difference of an altitude of an object as seen from the surface and the centre of the earth, or as measured from the apparent and true horizon is called "*parallax.*" Rays of light passing obliquely through the atmosphere, are so inclined, that a celestial object appears at a higher altitude than it really is. This inclination, is called "*refraction.*" Refraction is greatest at the horizon, and nothing at the zenith. An altitude of the sun, measured from the sensible horizon, and not corrected for dip, refraction, and parallax, is called an "*observed altitude.*"

The bearing of an object from due east or west when near the horizon, is called "*Amplitude.*"

The bearing of a celestial body from due north or south, is called "*Azimuth.*"

The earth in its progress round the sun in longitude, appears to be a little irregular, owing to the eccentricity of the earth's orbit. Its progress in right ascension is also irregular, owing to the relative direction of the earth's motion in the ecliptic, to the equinoctial—it being parallel about the the 21st of June and 22d of December, and at an angle of 23½° on the 20th of March and 20th of September. Time determined by the position of the sun is called "*apparent time.*" The difference between this and "*mean time,*" or time as it would be if the progress of the sun in right ascension was uniform, is called the "*equation of time.*"

The position of a place on the earth, is defined by its latitude and longitude.

A line protracted on a map or chart, passing through any given place, is called a "*line of position,*" consequently two lines of position of the same place, would by their intersection, define its position in latitude and longitude.

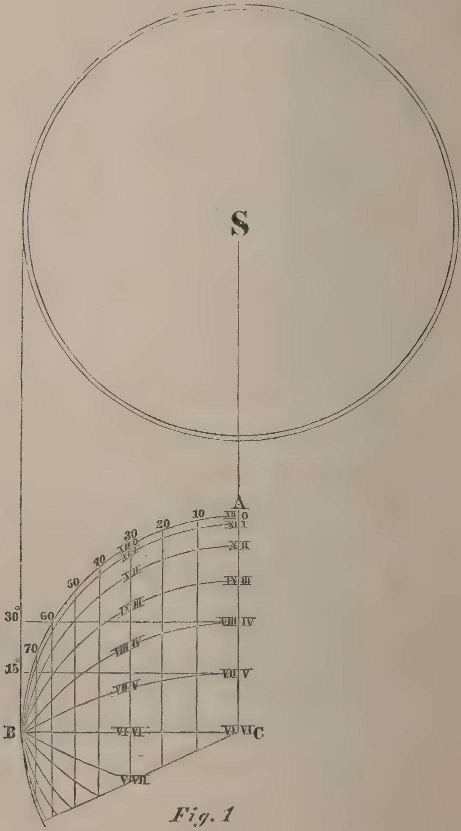
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Fig. 1

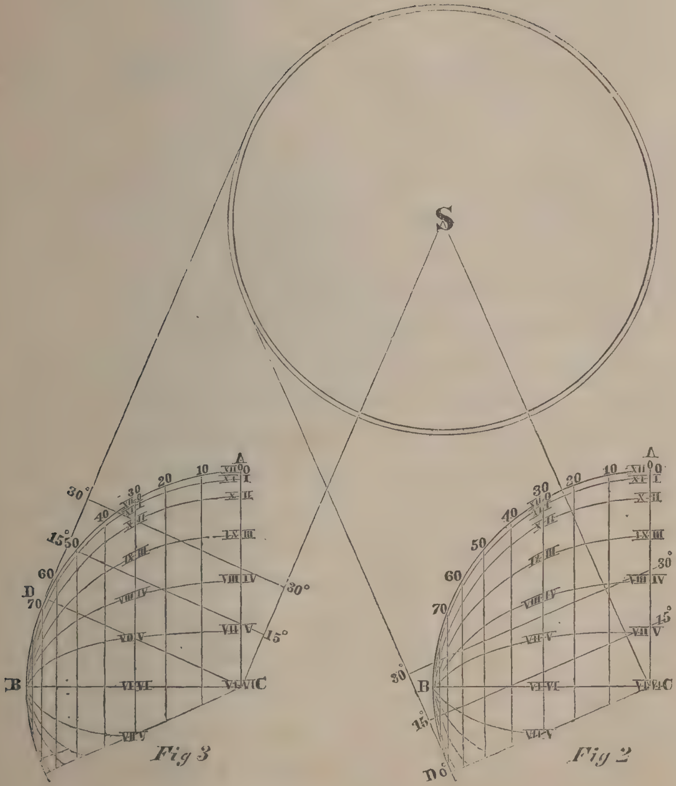
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Fig 3

Fig 2

DESCRIPTION OF THE HOROMETER.

On the plate of the Horometer, is a projection of the latitude and longitude, of a part of a sphere. See fig. 1, fig. 2, and fig. 3.

A. C. represents the equator, and the lines parallel to the equator, are lines of latitude. The curved lines are lines of longitude. Supposing these lines to remain stationary, while the earth turns on its axis, they give the position of a person in any latitude, at any time of day. If at 6 o'clock in the morning, a person should be under the line B. C. then in one hour from that time, he would be under the curved line marked VII. VII., and at the end of the next hour, he would be under the curved line marked VIII. VIII., and so on till 12 o'clock, when he would be under the circumference of the circle A. B. At 1 o'clock he would be under the curved line marked I, and so on. Thus a person is carried by the rotation of the earth, 15° every hour, and 1° every four minutes of time.

S. represents the sun's centre to be over the equator, in fig. 1. The sun always shines over half the globe, and would consequently in this case, shine just down to the pole B. and would be just visible to a person any where under the line B. C. In the A. M. this would be the sun-rise line, and in the P. M. it would be the sun-set line. Thus it appears that the sun would rise and set in all latitudes at VI o'clock. The altitude of the sun and other celestial objects, is measured from this line of illumination.

If a line parallel to the line of illumination be drawn say 15° above it, the line will show what time it would be to a person on any latitude, when the altitude of the sun is 15° high in that latitude. At the equator, it would be VII o'clock A. M., or V o'clock P. M., but in latitude 60° it would be VIII o'clock A. M. or IV o'clock P. M., and at every place between the equator and latitude 60°, in the P. M., the time would be between VI o'clock and V o,clock.

With an altitude of 30°, the time in the A. M. would be VII o'clock at the equator, but in latitude 60° with the same altitude, it would be XII o'clock at noon.

In fig. 2, the centre of the sun is at its greatest declination, 23°28′ from the equator, and on the same side of the equator that the observer is supposed to be; consequently, the sun would shine 23°28′ below the pole, or to the point D. The line D. C. would therefore, be the line of illumination, and where the line cuts any altitude, there will be indicated, the time of sun-rise for that latitude.

From the line of illumination and at right angles to it, is the altitude of the sun measured.

If lines are drawn parallel to the line D. C. and at different altitudes, they will by their intersection with the different latitudes, show the time of day in those latitudes, with the declination as above.

With this declination, it will be seen that the sun would rise at VI o'clock on the equator. In the latitude of 30° the sun would rise a little after V o'clock, and in latitude 70° it would rise before XII o'clock at night, that is, would be visible during the 24 hours.

Fig. 3, represents the sun at its greatest declination on the opposite side of the equator from that of the observer. C. D. would be the line of illumination.

It will be seen in this case also, that on the equator, the sun rises at VI o'clock, and in latitude 70°, it does not rise till after XII o'clock at noon, that is, it is not visible during the 24 hours.

A line drawn parallel to the line C. D. at any altitude, would indicate the time, by its intersection with any given latitude.

It is important to bear in mind that the point B, represents the North pole, if the observer is in North latitude; but it represents the South pole, if the observer is in South latitude.

From the foregoing explanation of figs. 1, 2, and

3, the Horometer will be readily understood. The movable index corresponds to the line C. D. in fig. 2 and 3, it can be moved either way to correspond to the declination, and is made fast by a thumb screw. The index has a vernier to read to minutes of a degree. It carries a hair parallel with it, and in a line with the centre on which it turns.

The point around which it turns, represents that point of the equator which is on the Horizon.

Connected with this index by a slide, is a scale of altitudes. It is divided into degrees, and again subdivided into five minutes up to the 50th degree, and from thence into subdivisions of ten minutes.

This scale compensates for the sun's semi-diameter, dip, refraction and parallax. The allowance for refraction and parallax is the same as is found in the usual tables. For the sun's semi-diameter, 16 minutes, and for dip, 4 minutes were allowed in the construction of the scale.

In taking the altitude of a star, the allowance of 16′ for semi-diameter should be taken off. Or if an artificial horizon is used 4′ must be added to the observed altitude, as there would in that case be no dip. Besides these two corrections, if the *corrected* altitude is given, the refraction must be added and the parallax subtracted.

The scale of altitudes carries a sliding T with a hair parallel to the hair on the index, and represents any line of equal altitude.

ADJUSTMENTS.

Move the index till its hair falls exactly over the VI o'clock line. The 0 of the vernier should now stand at 0 or 90 on the arc. Whatever it varies from it, is the index error, which can be adjusted by the small screws in the vernier, or the error must be allowed in setting the index at the declination or polar distance.

To adjust the T. hair, set the index at 90; slide the T. up to 7° 25′ and move the slide on the index so that the hair will reach from latitude 1° to latitude 28°. The hair should cut latitude 1° at VIh. 30m, and latitude 28°, at VIh. 34m. Should the hair not intersect as above, draw out the T. loosen the screws which hold the end pieces of the T. and adjust them as required.

PROBLEMS.

The following problems will illustrate the use of the Horometer.

The first four problems are here inserted, to make this a manual complete in itself, and to exhibit a simple method of working such examples as the book presents.

PROBLEM I.

TO CONVERT DEGREES AND MINUTES OF LONGITUDE, TO TIME.

Rule. Multiply the degrees and miles of longitude by four; the product of the miles, give seconds of time, and the product of the degrees, give minutes of time.

EXAMPLE.

32°23′ longitude.
4 multiplier.

2h. 09m. 32s. Time.

NOTE. The degrees and miles, each occupy two places of figures, and instead of carrying for 60 as is usual, it is more convenient to carry for 10 in its units place, and for 60 in the tens place.

PROBLEM II.

TO CONVERT TIME INTO LONGITUDE.

Rule. Reduce the hours to minutes, and divide by 4. The quotient arising from the minutes, gives degrees, and that of seconds gives miles.

EXAMPLE. It is required to convert 7h. 39m. 40s. time, to longitude.

459m. 40s.÷4=114°55′ longitude.

NOTE. In reducing the 7 hours to minutes, multiply the hours by six and add the product to the tens place of minutes. In dividing the 459 minutes by 4, there was a remainder of three minutes. This multiplied by 6 and added to the tens place in the seconds, makes 220 seconds, which divided by four gives 55′

PROBLEM III.

TO FIND THE CORRECT DECLINATION AND POLAR DISTANCE OF THE SUN.

Rule. Take out the sun's declination for noon, from the nautical almanac, and also the difference for one hour, by which, correct the declination for Greenwich time by chronometer, after or before noon, as the case may be.

If it is required to correct the declination to *ship's time*, correct for the hours before or after noon, and also for the supposed longitude, calling 15 degrees equal to one hour. This correction of declination to ship's time, is more easily done by proper tables, as table V. Bowditch's Navigator.

Having corrected the declination, if the declination and latitude of observation be both north, or both south, subtract the declination from 90°, but if one is north and one is south, add 90° to the declination, the result will be, the polar distance.

PROBLEM IV.

TO CHANGE APPARENT TIME TO MEAN TIME.

Take from the Nautical Almanac, the equation of time for the given day, also the hourly difference; correct the equation for the number of hours from noon of Greenwich by chronometer; apply the corrected equation to the apparent time, and the result is the true mean time.

NOTE. If required to correct it to *ship's* time it must be corrected for the hours from noon, and also for longitude, as in the case of declination.

PROBLEM V.

TO FIND THE TIME OF SUNRISE OR SUNSET.

Place the index of the Horometer at the *corrected* polar distance, and slide the T down to 0 of the altitude scale, where its hair cuts the given latitude, there, will be indicated the apparent time of sunrise or sunset, reckoning down the instrument in the P. M., and upwards in the A. M.

To the time thus found, should be applied the equation of time, which gives the mean time, when the sun's lower limb is apparently on the horizon.

EXAMPLE. Required the true mean time when the sun will rise on the first of December, 1852, in north latitude 52°, and 42°30′, and longitude 72° west.

Declination at Greenwich noon,	21° 53′ 40″	Diff for 1 hour 22″ 3.
Sub. cor. for 4 hours before noon,	1′ 29″	
	21° 52′ 11″	
Add correction for 72° longitude,	1′ 46″	
Correct declination,	21° 53′ 57″	
Polar distance,	=111° 53′ 57″	

Set the index at the polar distance 111° 54′, and slide the T down to 0 on the scale of altitudes. Where its thread cuts the latitude 52°, and 42°30′, there, will be indicated the apparent time of sunrise on those latitudes.

Lat. 52°	App. time, 8h 1m. M. time, 7h 50m 20s	Lat. 42° 30′	App. time, 7h 24m 15s. M. time, 7h 13m 35s.

NOTE 1. When the latitude is in degrees and minutes, the time may be read off on the two consecutive degree lines, one greater and the other less than the given latitude, and the proportion of difference of time allowed for the miles of a degree.

NOTE 2. If the observer's eye should be 25 feet above the water, the dip would be 5′, in that case, the T should be moved 1′ below the 0 on the scale of altitudes.

If the eye is only 9 feet above the water, the T should stand 1′ above the 0 of the scale. Corrections might also be made for the variation of the sun's semi-diameter from 16′, but it will generally be unnecessary.

NOTE 3. This problem is of importance, for several reasons. It often happens that the sun is visible at the time of rising or of setting, and is obscured the rest of the day. Again, an accident may happen to the sextant, rendering it unserviceable; in either case, if the time by chronometer be noted, when the sun's lower limb is on the horizon, the Horometer will enable the mariner to get his *longitude*, when the latitude is known, and will give him his *line of position* when his latitude is not known.

NOTE 4. To find the time when the *sun's centre* is apparently on the horizon, slide the T 16′ below the 0 of the altitude scale. To find when the sun's centre is truly on the horizon; all that is necessary, is to set the index at the polar distance, and read off the time where the hair of the *index* intersects the given latitude. The apparent time when the sun is really on the horizon in the example above, is in 52° latitude, 8h 3m 55s, and in 42° 30′ latitude, 7h 26m 30s.

PROBLEM VI.

TO FIND THE APPARENT TIME OF DAY.

Set the index, at the corrected polar distance of the sun, and slide the T on the scale of altitudes, till it stands at the observed altitude of the sun's lower limb. Where the thread of the T crosses the given latitude, there, will be indicated the apparent time of day.

EXAMPLE I. The polar distance being 71°37′; the observed altitude of the sun's lower limb, 18° 40′; required the apparent time A. M. in latitudes 42°, and 43°. In latitude 42° the apparent time is 6h 36m 24s. The latitude 43°, the apparent time is 6h 35m 40s.

EXAMPLE II. Given the polar distance 112° 25′, observed altitude of the sun's lower limb 13° 10′ P. M. required the apparent time in latitude 17° 30′, 18°, and 19°. Lat. 17° 30′, time 4h 27m. 56s. Lat. 18°, time 4h 26m 45s. Lat. 19°, time 4h 24m 22s.

PROBLEM VII.

TO FIND THE APPARENT TIME BY AN ALTITUDE OF A STAR.

Set the index at the polar distance of the star and slide the T 16′ below the observed altitude of the star. Where the T hair cuts the given latitude, read off the time, as though it was from an observed altitude of the sun, calling it A. M. if the star is east of the meridian, and P. M. if the star is west of the meridian. To this time, add the difference of the sun's and star's right ascension, if the *star's* right ascension is the greatest, but substract the difference if the *sun's* right ascension is greatest.

NOTE. A star must be selected, whose declination is less than 30°.

EXAMPLE I. A star east of the meridian, has an observed altitude of 28° 16′, polar distance of 95° 39′, latitude of observation 7° 45′, right ascension of 7h 30m 44s, and sun's right ascension corrected to the time of observation 11° 09′ 56″; required the apparent time of day.

Time by Horometer,	7h 57m 55s A. M.
Difference in Right Ascension,	3 39 11
Apparent time,	4h 18m 44s A. M.

EXAMPLE II. In latitude 48° 57′ N. a certain star's observed altitude was 22° 25′, and west of the meridian. Polar distance was 73° 50′, right ascension 4h 26m 30s, sun's right ascension 1h 40m 13s. Required the apparent time.

Time by Horometer,	4h 57m 33s P. M.
Difference in Right Ascension,	2 46 17
Apparent time,	7h 43m 50s P. M.

PROBLEM VIII.

TO FIND THE ALTITUDE AND APPARENT TIME WHEN THE SUN OR A STAR WILL BEAR DUE EAST OR WEST.

Set the index at the polar distance, and slide the T up or down the scale of altitudes, till the hair runs parallel to some longitude line, over the given latitude. The T will then stand at the observed altitude of the sun's lower limb, or 16′ above the required altitude of the star. The hair also will give the apparent time of the sun, or if it be a star, the apparent time is found by sliding the T down 16′ as in Problem VII.

EXAMPLE. The polar distance of the sun being 68° 43′, required the altitude of the sun's lower limb, and the time when the sun will be due east, in latitude 44°.

ANS. Sun's altitude 31° 30′, apparent time, 7h 36m.

NOTE. 1. It will be seen, that the time is nearly the same whether read off on latitude 43°, 44°, or 45°; consequently any ordinary error in latitude, would in these circumstances make no appreciable difference in time.

NOTE 2. The sun or star is never east or west, excepting when the polar distance is less than 90°.

PROBLEM IX.

TO FIND THE LONGITUDE BY ONE OBSERVATION OF THE SUN OR OF A STAR.

Find the apparent time from an altitude, when the sun or star bears east or west, and reduce this time to mean time. The difference between this time, and the time of Greenwich, turned into degrees and miles, will give west longitude if the ship's time is earlier than Greenwich time, and will give east longitude if the ship's time is later than Greenwich time.

EXAMPLE.

Correct Greenwich time,	6h 1m 16s	P. M.
Ship's mean time,	1 21 32s	P. M.
	4h 39m 44s=69° 56′ west long.	

Note. When the polar distance of the sun is not less than 90°, a star can almost always be found available, whose polar distance is less than 90°, and in this way, with one observation, the longitude is found. For it will be seen by reference to the Horometer, that an error of latitude to the extent of a degree, would make no appreciable difference of time.

PROBLEM X.

TO FIND THE LATITUDE BY TWO OBSERVED ALTITUDES.

Take the altitude of the sun's lower limb, and note the time. Then after the lapse of an hour or more, take an altitude and again note the time. Call the difference between the time of the two observations, the "*observed elapsed time.*" Set the index of the Horometer at the corrected polar distance, and the T at the observed altitude of the first observation. Assume two consecutive latitudes, one greater and one less than the latitude by account, and note the times on the assumed latitudes. Do the same with the second observation; find the two elapsed times as given by the Horometer on the two assumed latitudes, then by proportion, as the difference of the two elapsed times by the Horometer is to 60′, so is the difference between the elapsed time on the less latitude, and the observed elapsed time, to the miles to be added to the less assumed latitude.

EXAMPLE. The polar distance of the sun being 110°, and the latitude by account 44° 20′, the time per watch when the observed altitude was 8°, was 7h. 50m., and the time per watch with an altitude of 18°, was 9h. 12m. 45s. Times given by Horometer in latitude 44° for the two altitudes, were 8h. 16m. 9s., and 9h. 37m. 20s., and in latitude 45°, for the two altitudes time was 8h. 20m. 35s., and 9h. 45m. 30s.

Elapsed time by Horometer for latitude 44°	1h. 21m. 11s.
" " " " 45°	1 24 30
Difference of elapsed time,	3m. 19s. = 3.33m.
Elapsed time by Horometer for latitude 44°	1h. 21m. 11s.
Observed elapsed time,	1 22 45
3.33m. : 1.56m. :: 60′ : 25′	Diff. 1m. 34s. = 1.56m.

The latitude of observation was therefore 44°25′

NOTE 1. If the observed elapsed time should be either greater or less than the elapsed time at either of the assumed latitudes, the wrong latitudes have been assumed.

NOTE 2. This method is most accurate in high latitudes, and when the polar distance is greater than 90°.

NOTE 3. The declination should be usually corrected for the time of each observation.

NOTE 4. In some instances, an allowance should be made for the course and distance sailed between the times of observation.

PROBLEM XI.

TO FIND THE TIME OF TWILIGHT.

Set the index to the supplement of the polar distance, and slide the T to 18° altitude, or more accurately 17° 51′, where the hair cuts the given latitude, will be the apparent time when twilight begins in the A. M., or ends in the P. M., reckoning down the instrument in the A. M. and up the instrument in the P. M.

EXAMPLE. In latitude 43° north, and declination 15° north, when will twilight commence? Here the polar distance is 75°, the supplement of which is 105°. The index should therefore be set at 105°, which gives the time of twilight 3h. 6m. 20s. A. M.

PROBLEM XII.

TO FIND THE LATITUDE BY AN OBSERVATION OF THE SUN OR STAR WHEN ON THE MERIDIAN.

Set the index at the corrected polar distance and slide the T up the scale, till its thread cuts the circumference of the circle on the plate, at the supposed latitude. The difference between the altitude by Horometer and by observation, will be the error in latitude.

EXAMPLE. Being in latitude 37° by account, the sun's polar distance being 96° 15′ and an observed altitude of the sun's lower limb 46° 10′, Required the true latitude.

By Horometer in 37° latitude	46° 37′
By observation,	46° 10′
Difference,	27′
True latitude,	37° 27′

Note 1. If an altitude of a star is taken, substract 16′ from the altitude by the Horometer.

Note 2. When the latitude by account is in degrees and odd minutes, a latitude of some division on the arc may be assumed, instead of the latitude by account.

DESCRIPTION OF THE GEODETIC CHART.

It is believed that this chart is entirely new in its plan and design, and that by reason of its simplicity, compactness and accuracy, it cannot fail so to facilitate the various operations of practical navigation, as to secure the interest and confidence of all navigators, who will make themselves familiar with its uses.

It is constructed upon the principles of Mercators projection, and is so arranged as to be adapted to any longitude, and to any latitude as high as 75 degrees.

In North Latitude the top of the Chart is north, and the right hand east; but in South Latitude, the top of the Chart is south, and the left hand east.

The perpendicular lines, running North and South, are lines of longitude, five miles apart; the heavier lines a, a′, b, b′, c, c′, are degree lines, and they may represent any series of degrees.

The horizontal lines, numbered in the margins from 1° to 75°, together with the lower line E. E., to which these lines above all have reference, represent lines of latitude. The line E. E. may represent the lower of any two consecutive degrees; the higher of the two degrees, is found above, as numbered in the margins. For instance, if we assume two degrees of latitude, as 45° and 46°, the line E. E. will then represent the latitude 45°, and the line numbered in the margins 46, will represent the other assumed latitude. The distance apart of these two lines, being the distance between 45° and 46° of latitude, on Mercators chart, upon the same scale.

So also, if we assume 74° and 75° the line E. E. will represent 74°; from this to the 75 in the margins, is likewise the distance on Mercators chart between 74° and 75° of latitude.

The "Diagram of distances" at the left hand, is designed to show upon its perpendicular lines, the relative measurement in miles, of the several degrees of latitude, from the equator to 75°, as numbered at the top and bottom. The length of these degrees, is subdivided into five miles intervals, by the curved lines, which are numbered on the side margins of the diagram. For instance, the distance between 74° and 75° of latitude, is the length of the line in the diagram, marked at the bottom 75, and the distance between 45° and 46° of latitude, is the length of the line 46 or the line next beyond 45.

By reference to the intersecting curved lines, as marked in the margins, 5, 10, 15, &c., any number of miles, upon any given degree of latitude on the chart may be measured.

The graduated arc on the chart, having O for its centre, is designed to be used in ascertaining the azimuth or the amplitude of the sun—the direction of a line of position—and for laying off the direction of any course made in sailing.

The following problems will illustrate the uses of the chart.

PROBLEM I.

TO FIND THE AMPLITUDE AND AZIMUTH OF THE SUN.

Example I. Required the sun's true amplitude in latitude 39°20′ N. when the declination is 23°28′ S. Find the difference of the time of sun rising on two consecutive latitudes, between which is the given latitude—turn this difference of time into degrees and miles, and project it upon the chart as directed below.

Time of sunrise in Latitude 39° = 7h. 22m. 10s.
Latitude 40° = 7h. 25m. 25s.

Difference, 3m. 15s. = 0° 49′

From the centre longitude line d, d′, and upon lat. 40°, point off 49 miles (eastward because the time in 40° lat. is *later* than in lat. 39°,) then from the centre O, draw a line to the arc, through the point made on lat. 40°, (or lay a straight edge upon these points) where this line cuts the arc, read the true amplitude, 32°30′ S. The same line will also show the azimuth, by the figures outside the arc to be S. 57°30′ E.

NOTE.—The assumed latitude which gives the time *later*, gives the longitude further *east.*

In north latitude, if the higher assumed latitude gives the time earlier in the P. M. or later in the A. M., the sun or star is southward, if otherwise northward. In south latitude, vice versa.

Example II. In lat. 51°52′ N. the polar distance 73°22′, the observed altitude of the sun's lower limb being 39°17′; required the true azimuth.

Apparent time in lat. 51° = 8h. 53m.
do. do. lat. 52° = 8h. 56m. 8s.

Difference, 3m. 8s. = 47′ Azimuth S., 63°55′E.

In this case as in the first example, on the higher lat. 52° and at a distance of 47′ to the east of the centre longitude line d, d′, (because time on that latitude is *later*,) project a point; draw a line from the centre O through this point on lat. 52°, and it cuts the arc at 63° 55′.

PROBLEM II.

TO FIND A LINE OF POSITION, WITH ITS BEARING; AND THE AZIMUTH OF THE SUN.

Given the polar distance 68°25′, lat. by reckoning 55°50′ N., observed altitude of sun's lower limb

21°20′; equation of time 2m. 28s. additive; chronometer time 6h. 42m. 10s. Required the line of position, its bearing—and the true azimuth of the sun. Assuming the two consecutive latitudes nearest the latitude by reckoning, viz: 55° and 56°, we find

True mean time in lat. 55°	6h. 30m. 30s.	
Chronometer time,	6h. 42m. 10s.	
Difference,	11m. 40s.	= 2° 55′ West long.
True mean time in lat. 56°	6h. 29m. 38s.	
Chronometer time,	6h. 42m. 10s.	
Difference,	12m. 32s.	= 3° 08′ West long.

For the two degrees longitude, assume any degree line as c, c′, to the westward of which point off 55′ on the line E. E. The degree line d, d′, would of course represent 3° of longitude. To the west of this line, on lat. 56°, point off the 8′. A line passing through these two points, will be the required line of position. A line parallel to this, from the centre O, to the graduated arc, will give the bearing of the line of position, North 7°20′ West, or reading from the figures outside the arc, it gives the azimuth N. 82° 40′ East. A line of position transferred to a common chart, shows the bearing of any land through which it passes.

To test the accuracy of the above work, assume the latitudes 56° and 57°, or 54° and 55°, and protract the line of position. If the work is right, the two lines will be nearly parallel; as nearly so, as the curve of the longitude line between the last two given latitudes, is like that between the first two, upon the Horometer.

PROBLEM III.

FROM ANY POINT IN ANY GIVEN LINE OF POSITION, TO PROTRACT ANY COURSE AND DISTANCE.

Required to lay off a distance of 32 miles N. N. E. from any line of position, as in the preceding example, between latitudes 55° and 56°.

A line from the centre O, to the graduated arc, at 22°30′ gives the direction N. N. E., and any line parallel to this direction line, cutting the given line of position at any point, will be the given course. Then lay off the given distance 32 miles from the line of position upon the given course.

Note. In laying off the distance of any course, if the direction is due East and West, the distance should be taken from the line E. E. or from the first latitude line in the diagram. When the course is in any other direction than East and West, then by proportion, 90° is to the number of degrees the course is from East and West, as the given latitude line is to the latitude in the diagram from which the distance of the course should be taken. In the example above, the course is 67° 30′ from due east; then 90° : 67°30′ : : 56° : 42°. We should therefore, take the distance of the course from the 42° latitude line in the diagram.

PROBLEM IV.

TO FIND THE LATITUDE AND LONGITUDE OF THE PLACE OF OBSERVATION BY TWO OBSERVED ALTITUDES.

Find the line of position by the first observation, as directed in the preceding Problem II. Then, from any point in that line lay off the course and distance sailed between the times of the two observations. Through that point draw a line parallel to the first, and call it the second line of position. Next, find the line of position by the second observation, and where this line cuts the second line of position, is the true point of position at the time of the last observation. The longitude of the point of intersection is at once shown. The miles of latitude are determined by taking the distance of the point of intersection from the line E. E. and applying it to the corresponding latitude line in the diagram.

Note I. If the course and distance sailed over between the times of observation be laid off back from the last line of position, and a parallel to it be drawn, where this parallel cuts the first line of position, will be the place of the observer at the time of the first observation. The true point of position can be readily transferred to a common chart.

Note II. Could the course and distance sailed be accurately known, the most suitable time for the two observations, would be one in the A. M.

and one in the P. M., when the azimuth is about 45 degrees: but as inaccuracies are most likely to occur in the estimated course and distance, resulting from currents, as well as in the sailing, it is better that there should be less time between the two observations. Two observations might be taken in the A. M., or two in the P. M., or one in the A. M. and the latitude at noon, would determine the latitude and longitude of the place of either observation.

Note III. By protracting a number of lines of position from a series of observations in a calm, all the lines should intersect at the same point; their failure to do so would indicate a current, and show its direction. Such a series of observations made on land, would be an accurate method of determining the latitude and longitude, and if all the lines of position did not intersect at one and the same point, it would show inaccuracy in the operation. One observation when the sun's lower limb is apparantly on the horizon in the A. M., and another observation an hour or two afterwards; or one an hour or more before sun-down, and another just as the sun's lower limb touches the horizon, would be suitable times; when the polar distance is greater than 90°.

PROBLEM V.

TO FIND THE LATITUDE AND LONGITUDE FROM THE ALTITUDE OF TWO STARS.

Select two known stars whose bearings differ several degrees—the nearer 90° the better. From an altitude of each, taken as near the same time as practicable, protract the lines of position upon the chart by Problem II. The point of intersection, will be the true latitude and longitude of the place of observation.

EXAMPLE. Being in Latitude 38° 35′ by account, with Spica and Aldebaran above the horizon, Spica bearing Easterly and Aldebaran Westerly.

Spica's R. A.	13h. 17m. 27s.	Aldebaran's R. A.	4h. 27m. 29s.
Sun's R. A.	16 10 12	Sun's R. A.	16 10 12
Diff. in R. A.	2h. 52m. 45s.	Diff. in R. A.	11h. 42m. 43s.
Spica's Decl. S.	10° 23′ 32″	Aldebaran's Decl.	16° 12′ 34″
Polar distance,	100 23 32	Polar Distance N.	73 47 26
Assumed latitude,	38 00 00	Assumed lat.	38 00 00
Observed Alt.	16 51 00	Observed Alt.	22 41 00
Time A. M.	8h. 3m. 55s.	Time P. M.	4h 54m 52s
Add	12	Add	12
	20h. 3m. 55s.		16h. 54m. 52s.
Diff. in R. A.	2 52 45	Diff. in R. A.	11 42 43
Apparent time,	17h. 11m. 10s.	Apparent time,	5h. 12m. 09s.
Equation of time,	12 10	Equation of time,	12 10
Mean time,	16h. 59m. 00s.	Mean time,	4h. 59m. 59s.
Greenwich time,	20 44 44	Greenwich time,	8 44 44
Difference,	4 | 3h. 45m. 44s.	Difference,	4 | 3h. 44m. 45s.
West Longitude,	= 56° 26′ 00″	West Longitude,	= 56° 00′ 11″
Ass. lat. 39°, time,	8h. 6m.42s.	Ass. lat. 39°, time,	4h 55m 09s.
Time on lat. 38°,	8 3 55	Time on lat. 38°,	4 54 52
Difference,	4 | 2′ 47″	Difference,	4 | 17s.
Diff. in long. (*easterly because later,*) =	41′ 45″	Diff. in long. (*easterly because later.*) =	4′ 15″
West Longitude,	= 55° 44′ 15″	West Longitude,	= 55° 55′ 56″

Protracting the two lines of position upon the Chart, they intersect in Longitude 56° 9′ 45″ West, and Latitude 38° 24′ North. The Azimuth of Spica S. 61° 40′ East. The Azimuth of Aldebaran north 86° 45′ west.

Note 1. This method has this advantage, that it is not subject to error on account of the course and distance sailed between the time of two observations. If three stars were observed, the work would be tested by the nearness with which the three lines of position intersect at the same point.

Note 2. In a calm, two such observations would determine accurately the course and strength of currents. The author is not aware that this method has heretofore ever been resorted to in determining the currents at sea.

Note 3. This method, in connection with the Horometer, (See Problem VII, page 17) becomes so perfectly simple and short, and if observations are taken in the twilight, so reliable, that it should not on any account be neglected.

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60, 22

4, 31, 2

1-22-56 9-51 8.2

2:04=27 = 15.47

15-31

15-32

15-46

17-47

28-3

29-17

30-12

43-50